LA-UR-83-2312

CONF-831047--81

LA-UR--83-2312

DE83 017307

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SUBMITTED TO American Nuclear Society Meeting, San Francisco, CA, October 30 - November 4, 1983.

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FORM NO 836 R4
ST NO 2629 5/81

MASTER

CHOOSING AN IMAGING SYSTEM

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This paper provides a trade-off study between various gamma-ray imaging techniques. In choosing an imaging method it is important to determine the actual information needed and then concentrate the available imaging rescurces in the most efficient manner. We will discuss techniques for imaging gamma-ray self-emitting sources, such as radioisotopes and some celestial sources, by defining generic groups of techniques and providing the rational for selecting a system which concentrates the resources.

In general, techniques can be classified as either non-imaging systems, focussing systems, or geometric systems. Focussing systems will always provide a better signal-to-noise (SNR) than other systems but they will not be discussed further since they usually only operate below 10^4 eV. An example of a useful non-imaging system is a situation where the needed information is only whether or not a source is present. A simple detector with no imaging can often distinquish the presence of a source better than an imaging system.

The geometric systems can be classified into generic groups in two ways. First, one can distinguish those that produce a spatially encoded image, by a position-sensitive detector from those that produce a temporally encoded image via motion of a detector. In addition, techniques can be further classified by whether they are non-multiplexed, spatially multiplexed, or frequency multiplexed (see table I). Spatially- and temporally-encoded systems usually give approximately the same SNR. The trade-off between spatial or temporal encoding is based on the following considerations:

1) If the source has temporal variations then the temporal option is usually not considered.

2) One must consider the difficulty of building a position-sensitive detector vs. building a moving detector.

3) The temporal systems obtain their resolution from how fine the opaque grids can be constructed whereas the spatial systems obtain their resolution by how small the spatial resolution is in the position-sensitive detector. Thus, the state-of-the-art in grid construction and position resolution must also be taken into account.

A multiplexed system provides an advantage by the fact that it has a higher throughput but it also has a disadvantage since the noise in every reconstructed pixel is the sum of all the noise in the source.[1] Thus, if the source is very diffuse, or if one is studying low-intensity regions on a high-intensity background (such as in many medical applications) a non-multiplexed system is often preferred, despite the fact that one might collect 10^3 less photons.

Spatially multiplexed systems are based on special binary patterns, the most efficient of which are called uniformly redundant arrays (URA). URAs have the property that the multiplexing and reconstruction does not introduce artifacts[2] and they are especially useful for studying the high-intensity regions of a diffuse source or locating a set of point sources (such as in many astrophysical applications). At very high energies, time-modulated URAs[3] offer the additional advantage of not requiring a position-sensitive detector and, thus, can solve the severe problem of a spatially varying detector background.

A general rule for URAs is that the number of spatial resolution elements in the detector is the number of pixels obtained in the reconstructed source.

When one cannot build a detector with sufficient number of elements or when one does not require the full coverage of the spatial frequency space because of a priori knowledge, then a frequency multiplexed system should be considered. In such a system, grids are arranged so that the resulting interference pattern gives a point in the spatial Fourier transform of the source either by producing a spatial pattern (i.e., Fourier transform camera[4]) or by producing a temporal pattern (i.e., modulation collimator[5,6]) By measuring many such points, the source can be reconstructed.

Finally, it is possible to design hybrid systems that address very particular questions. We present a new concept called a source position encoder that concentrates the available resources to produce only a digital number which is the position of the source in the field of view.

This work was done under the auspices of the U. S. Dept. of Energy.

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Table I. Generic Geometric Imaging Systems and Their Uses

Type of Multiplexing	Instrument Name: Spatial Variation	Instrument Name: Temporal Variation	Typical Use
none	Pinhole	Collimator	diffuse sources, cold spots
spatially	Uniformly Redundant Arrays	Time-Modulated Uniformly Redundant Arrays	point sources, hot spots, complex sources
Frequency	Fourier Transform Cameras	Modulation Collimator	sources with some *a priori* knowledge, when resolution of detector is insufficient for URA